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Techno-economic parametric assessment of solar power in India: A survey

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A B S T R A C T

There are two ways by which solar energy can be harnessed viz. solar Photo-Voltaic (PV) and Concentrating Solar Power (CSP). This paper focuses on the parameters required for the commissioning of solar power plants in India using these technologies. The key parameters have been identified through the literature review and discussion with the experts. The parameters thus obtained, are classified under PV and CSP technologies and then categorized into technical and economical parameters. A survey is conducted to understand the perceptions of Indian key players in the area of solar energy and to rank forty one identified parameters. Analysis of survey shows that location of the site and direct investment cost are the highest preferred technical and economical parameters respectively. The results of this study will help decision makers and policy makers of solar technologies in India.

Contents

1. Introduction

India lies in the sunniest regions of the world with 250–300 clear sunny days. Solar energy, if harnessed can play a major role in reducing India's power deficit. Various technologies are used to convert solar irradiation into usable form of energy like thermal and electricity [1]. Solar thermal energy can be utilized for process heating applications, solar water heating systems, drying of biomass etc. Electricity is generated though solar, mainly in two ways, one being direct conversion of solar radiation into electricity (using PV) and other by indirect conversion in which concentrated solar energy heats up fluid stream which runs the conventional thermal power plant cycles [2]. PV which is direct electricity generation technology is proven and tested commercially. Multi-megawatt generation plants based on PV technology have already been in operation all over the world for decades. The Concentrating Photo-Voltaic (CPV) is comparatively an emerging technology as compare to PV [3]. In India, the power generation through PV has gained pace after the year 2002 [4]. CSP systems which uses indirect conversion technology are categorized by the way solar energy is focused and received. These systems are classified as (a) parabolic trough collectors (b) linear Fresnel collectors (c) central receiver systems (d) parabolic dishes and (e) Scheffler systems [5]. This classification is based on their focus geometry as

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either line-focus concentrators (parabolic-trough collectors and linear Fresnel collectors) or as point-focus concentrators (central receiver systems, parabolic dishes and Scheffler systems).

The Jawaharlal Nehru National Solar Mission (JNNSM), one of the eight National Missions under National Action Plan on Climate Change, which was launched on 11th January 2009 with funding of USD 930 million. It is an ambitious mission to make India a global leader in solar energy by generating 20,000 MW of solar power by 2022 [6]. The JNNSM is sub divided into three phases. Phase I targeted for 1000 MW by end of March 2013 and crossed the set target with installed/ allotted capacity of 1236.48 MW with stipulated period of time. Phase II has the target of 5000 MW till 2017. As of January 2014, the cumulative grid connected installed capacity of 2208.36 MW and off grid 159.77 MW of solar power has been achieved [7]. Majority of the solar installed capacity is of PV as compared to that of CSP.

As compared to PV, CSP technologies started with slow pace since its inception in nineties due to various factors favoring PV like decreasing cost of PV, ease of commissioning and less maintenance of PV systems, and to some extent poor political and financial support for CSP by Government of India. For instance, it was planned to set up a 35 MW power plant based on CSP in Mathania, Rajasthan in year 1994, but the project has not seen the light of the day due to lack of encouragement from government resulting in short of sufficient bidders and contractors. But, with the onset of JNNSM the scenario is now changing, resulting in rapid development in the area of CSP [8]. From 2010 to 2012, many CSP projects were introduced in India. The government of Rajasthan reinitiated the Mathania solar power project with an additional capacity of 105 MW from conventional sources, giving combined capacity of 140 MW integrated solar combined cycle power plant [9]. The current installed capacity of CSP in India, as of July 2013, is 55.5 MW which is just 2.51% of PV installed capacity [10]. This disparity between PV and CSP is due to the various factors like maintenance, grid connectivity, ease of commissioning, government policies; availability of water, which is the key factor for CSP plants for both cleaning of mirrors and running turbines specially in arid regions like western Rajasthan and Kutch of Gujarat. Despite these problems, CSP is gaining momentum in these areas as this part of the country is blessed with high solar insolation and CSP has advantages like it can be hybridized with conventional fossil fuel system and can generate power continuously with thermal storage. The CSP plants with collective capacity of 585 MW are under construction in Rajasthan, out of which only 52.5 MW has been operational till date. An operational plant of 1 MW, in Gwal Pahari Haryana, is solely for research and development purpose of Ministry of New and Renewable Energy (MNRE). In Andhra Pradesh around 100 MW and in Gujarat 45 MW of CSP plants are under construction. Similar to CSP, many projects on PV are also under constructions in Gujarat, Rajasthan and Tamil Nadu. It is expected that PV and CSP will further gain momentum in near future, thus makes the need to review technical and economical parameters for PV and CSP especially in Indian context. This paper tried to find out the key parameters required for the deployment of solar technologies in Indian context.

2. Review of techno-economic assessment

Techno-economic assessment for various solar power generation technologies, *viz*, PV and CSP, has been attempted by various researchers. For instance, In PV technologies, Fthenakis [11] gave a technical, geographical, and economical feasibility for solar energy to supply the energy needs of the USA. A solar power plant pre-feasibility study by Cameron [12] shows that the size of the plant is a key determining factor, followed by location and cost. However the details presented are with reference to Australian scenario. The Handbook for PV systems [13,14] shows that temperature also plays an important role on the life span of solar cells. The report describes the use of solar equipments like modules, inverters, batteries etc. A study by Branker et al. [15] found out that solar thermal electricity is an economically viable technology under favorable conditions, i.e. in areas with high insolation levels. At a global level, the International Energy Agency (IEA) has prepared technology roadmaps for PV as well as for CSP [16–18], which projects that solar electricity could represent up to 20% to 25% of global electricity production by 2050 and that CSP could supply over 10% of the world's electricity by the same year. In India, a roadmap is prepared by the MNRE [19], under the authority of Government of India. Soni and Mellacheruvu [4] discussed in detail about Concentrating Solar Photovoltaic (CPV) and possible impact of the same as compared to PV in Indian market.

“A research on CSP with levelized cost” by Nezammahalleh [20] presented the technical and economical assessment of the integrated solar combined cycle power plants in Iran. In the research article, thermal efficiency, capacity factor, environmental considerations, investment, fuel and O&M costs are the main parameters considered for technical and economical assessment of solar power plants. Eck et al. [21] suggest that direct steam generation is a promising option to improve the solar thermal electricity generation efficiency. According to Mills [22] solar thermal electricity generation systems are emerging among the renewable energy technologies available. A research by National Renewable Energy Laboratories (NREL) shows that, in USA large scale deployment of CSP plants with careful land and water usage would have ecological impacts which can be managed through sensible deployment of solar resources [23]. One of the key works in the field of CSP is done by Vogel and Kalb [24], which discusses the technical and cost factor for commissioning of solar thermal based power plants. Morin [25] considered the technical parameters like heliostat fields, operating temperatures, thermal storages etc for his study. Assessment report on parabolic trough and solar tower by Sargent and Lundy [26] shows that in a long run CSP will prove to be the main source of power generation technology. From the above literature survey, it was found that most of the research work has been done in the area related to the development of PV and CSP technologies. In case of technical assessment the concept of grid parity and levelized cost of electricity is used [27]. The technical details like location and weather is also discussed in some of the research papers, however they are restricted to particular technologies and location. Economic assessment comparisons of various technologies are done on the basis of direct cost and operational cost.

Literature also showed some research work related to expert survey in the field of renewable energy. For instance, Heo et al. [28] surveyed using five decision making criteria and seventeen factors for the assessment of renewable energy dissemination program in Korea. Similarly, Komendantova et al. [29] took a brief survey from the stakeholders on the potential barriers in renewable energy and discussed the political risks connected with technology. A report by International Renewable Energy Agency [30] showed the perception of solar parameters for the use of ‘Global Renewable Energy Atlas’ from the responses of ‘Solar and Wind Resource Assessment’ tool users. Another survey report for IEA by Group on Earth Observation [31] on Solar Heating and Cooling Program shows the essential parameters of solar energy for the improvement of solar resource assessment software. Research work by Bosetti et al. [32] discussed the elicitation survey from 16 experts from Europe. The survey was on future prospects of PV and CSP technologies with Research, Development

and Demonstration investment criteria. They also discussed the barriers and policy making recommendations from the same survey in their report [33]. However the results and discussion of the work is related to the European perception with policy and decision making factors.

For India, a report by Beerbaum [34] presented the techno-economic analysis of solar thermal power generation in the country. World Institute of Sustainable Energy (WISE) [35] and CSP Today [36], also performed the technical assessment for a few states and shows that the states like Rajasthan, Gujarat and Andhra Pradesh have vast potential for CSP technologies. It also discusses the barriers and policies for the CSP Technologies. A research paper by Purohit and Purohit [37] presented the technical assessment where a comparative study has been done for various Indian locations for commissioning of CSP plants in comparison with existing solar thermal power plants of Spain. A research paper by Sharma et al. [38] discusses the solar policy and barriers for India. Ramachandra et al. [39] has considered technical parameters like location and weather in their study. Economic assessment comparison of various technologies on the basis of direct cost and operational costs are performed by various researchers [34,35,40].

It is clear from the literature review that for the Indian scenario, techno-economic parametric assessment of solar technologies, which contains both PV and CSP, has not yet done. Though expert elicitation work [32] by survey has been done for European policies, but for Indian context, there exists a gap to correlates the parametric assessment with expert survey. Continuing our previous work on the assessment of CSP technologies, [40,41] this paper is an attempt to provide new arena for the assessment of solar technologies, both PV and CSP, in Indian context.

3. Research methodology

3.1. Selection of parameters

From the discussion with the experts on various solar power generation technologies, various parameters like land requirement, water supply, azimuth angle, albedo etc., were found out which mainly comes into the picture for the commissioning of the plants. For both PV and CSP technologies, various factors like land requirement, installation cost, solar angle, solar multiple etc., were identified from literature. The parameters are then combined together according to their nature. For example, the cost of equipments, civil work, site preparation cost are taken as direct investment cost. Similarly, solar angle, azimuth angle etc., are taken into solar resource assessment and henceforth. Thus, out of more than hundreds of technical and economical parameters, forty one parameters were taken under consideration. These parameters were then categorized into four categories *viz.* economical parameters, technical parameters which are common to

Table 1
Parameters.

Economical Parameters (common for both technologies) (*A*)	P1	Direct investment cost
	P2	Operation and maintenance cost
	P3	Insurance cost
	P4	Loan interest rate
	P5	Payback period/IRR or ROI
	P6	Consideration of inflation rate
	P7	Net salvage value (Depreciation value)
	P8	Power Purchase Agreement (PPA)
	P9	Taxes
	P10	Necessities of government subsidies
	P11	Land cost
	P12	Renewable energy certificates (REC) mechanism
Technical Parameters (common for both technologies) (*B*)	P13	Location
	P14	Capacity utilization factor of Plant/System (CUF)
	P15	Need of lightning arrest for PV and CSP
	P16	Annual efficiency of the power plant
	P17	Solar field
	P18	Operating temperatures of the system
	P19	Solar resource assessment
	P20	Washes/Cleanliness of mirrors or collectors
	P21	Area of collector and absorber
	P22	Grid connectivity
	P23	Need of fire alarm systems
	P24	Hours of full load operations
	P25	Impact of local climate
	P26	Local Operations & Maintenance support
Technical Parameters (For PV) (*C*)	P27	Type of cells/panels used
	P28	Mismatch in connections (series and parallel combinations)
	P29	PV array self shading (shadow) considerations
	P30	Electrical accessories for Photovoltaic
	P31	Need of Concentrating PV (CPV) module
	P32	Performance ratio
Technical Parameters (For CSP) (*D*)	P33	Type of CSP technologies
	P34	Thermal storage
	P35	Heat transfer fluid
	P36	Easy availability of water
	P37	Tracking (Type, mode etc)
	P38	Losses in CSP
	P39	Mirror/Heliostat properties
	P40	Materials used
	P41	Module mounting structure

both PV and CSP and individual technical parameters for PV and CSP. The forty one parameters, under consideration for assessment are shown in Table 1.

3.2. Survey design

Since majority of the criteria were technical, the evaluation of these criteria was planned to be through a survey. Questionnaire was designed for evaluation of different parameters. Structured questionnaires were prepared, tested, validated, modified and opinion is collected from various experts through web base survey. The experts were identified from groups such as academicians, working professionals (which include policy maker, manufacturers, engineers etc.), researchers and Non Government Organizations (NGOs). The few respondents like research scholars, students and individuals working in this area were classified into miscellaneous (or others) category since their percentage was quite less. The experts were asked to assign importance of the parameters on a 10 point qualitative linear scale. The 10 points were given for Very High (VH) importance level, which had highest level of parameter judgment by the respondent. Similarly 8 points were given for High (*H*) which shows dominance of the judgment, 6 points for Medium level (*M*), which shows compromising level of judgment, 4 points for Low (*L*), which shows lower level of judgment and 2 points for Very Low (VL) level, which shows peripheral level of judgment for the given parameter.

3.3. Computation of weightage

Weighted average values have been computed for importance of parameters on 10 point scale. The weighted average value are calculated by the given formula,

$$Weightage = \frac{\sum_{i}^{j} W_j N_j}{N}$$

Where W_j indicates the importance of jth parameter (on assigned scale) by the numbers of respondents, N_j for the parameter and N are the total number of respondents [42]. W_j is calculated by taking the mean of overall responses for a particular jth parameter. The assigned weightage for various groups identified for the present problem are computed using Microsoft Excel. The computed weightage for the 41 parameters are categorized according to four different groups and the average values of these groups of parameters are calculated. From the survey, 70 suitable responses are taken into consideration. The weightage obtained from the survey is then normalized to arrive at the key priorities. The methodology used for normalization is shown in Table 2.

The weightage of each parameter is calculated and the value is normalized according to the mentioned formula. The normalized value is shown in Table 3.

4. Results and discussion

The 70 suitable respondents are classified according to their field of expertise. Fig. 1 shows the psychographics of the respondents according to their field of expertise.

The responses are then sorted and analyzed. The weightage of each parameter is calculated and the value is normalized according to the formulae mentioned in Table 2. The analysis of normalized performance of parameters is then classified according to respondents' field of expertise. The comparison thus made is shown in Table 4. Here normalization technique is used to arrive at the parameter weights and hence the final results. The results obtained from the comparison are summarized in the graphs as shown in Fig. 2 to Fig. 6. The graphs depicts the importance level of category wise parameters according to the expert groups.

Preferences given by experts to various economical parameters for both PV and CSP are as shown in Fig. 2. It is clearly observed that, according to the professionals the weightage of *direct investment cost* (0.026) and *power purchase agreement* (0.026) holds the top preference, while *insurance cost* (0.0161) and *net salvage value* (0.0149) are least preferred. Researchers preferred *direct investment cost* (0.027) followed by the availability of *government subsidies* (0.023) while *insurance cost* (0.0159) and *inflation rate* (0.0168) are given lowest importance. Educators, NGOs and others followed similar trend.

In case of technical parameters for both PV and CSP, the professionals preferred the *location of the site* (0.026) and *solar resource assessment* of the area (0.025) the most, while need of the *fire alarm systems* (0.017) is given lowest priority. Researchers also gave the first preference to *location of the site* (0.028) followed by *Capacity utilization factor (CUF) of Plant* (0.025) and like professionals the need of *fire alarm systems* (0.168) is least preferred. Educators favored *solar resource assessment* (0.0262) followed by hours of *full load operations*, *area of collectors*, *annual efficiency* and *CUF of plant*, all given a weightage of 0.0247. NGOs chosen *government subsidies* (0.0298) while miscellaneous opted for *CUF of the plant* (0.0296) the most. The comparison is shown graphically in Fig. 3.

Fig. 4 shows the priorities given to technical parameters for PV alone. The importance is given to *type of cell used* (0.026) and *performance ratio* (0.025) by professionals and *self shading consideration* (0.0251) along with *performance ratio* (0.0251) by researchers. Educators preferred *performance ratio* (0.0262), while NGOs and rest of the respondents gave maximum importance to *type of cell used*, with the weightage of 0.0283 and 0.0276 respectively. *Concentrating PV* is given lowest preference by most of the respondents.

The comparison of technical parameters for CSP is represented graphically in Fig. 5. The *type of CSP technology* holds the highest preference by professionals (0.0258) followed by *mirror properties* (0.023). While the researchers favored importance of *thermal storages* (0.0268) more than the *type of CSP technologies* used (0.0262). *Easy availability of water* (0.0262), *type of CSP technologies*

Table 2
Normalization of data.

	Parameter weights	Parameter 1 x	Parameter 2 y	Parameter 3 Z
Parameter 1	x	1	y/x	z/x
Parameter 1	y	x/y	1	z/y
Parameter 1	z	x/z	y/z	1
Column Total		$a=1+x/y+x/z$	$b=y/x+1+y/z$	$c=z/x+z/y+1$
Division of 1st Row		$p=1/a$	$q=(y/x)/b$	$r=(z/x)/c$
Division of 2nd Row		$l=(x/y)/a$	$m=1/b$	$n=(z/y)/c$
Division of 3rd Row		$e=(x/z)/a$	$f=(y/z)/b$	$g=1/c$

Table 3
Normalized parametric weightage for all parameters.

Parameters	Professionals	Researchers	Educators	NGOs	Others	Overall
P1	0.0262	0.0271	0.0262	0.0314	0.0257	0.0268
P2	0.0177	0.0202	0.0174	0.0157	0.0217	0.0187
P3	0.0161	0.0159	0.0174	0.0157	0.0158	0.0161
P4	0.0235	0.0202	0.0233	0.0204	0.0197	0.0219
P5	0.0248	0.0228	0.0262	0.0267	0.0237	0.0242
P6	0.0172	0.0168	0.0218	0.0173	0.0178	0.0174
P7	0.0149	0.0171	0.0174	0.0141	0.0217	0.0162
P8	0.0260	0.0213	0.0262	0.0188	0.0276	0.0239
P9	0.0184	0.0196	0.0174	0.0157	0.0138	0.0184
P10	0.0209	0.0233	0.0233	0.0283	0.0257	0.0227
P11	0.0184	0.0208	0.0203	0.0204	0.0217	0.0197
P12	0.0212	0.0221	0.0218	0.0220	0.0296	0.0219
P13	0.0264	0.0282	0.0233	0.0251	0.0276	0.0268
P14	0.0255	0.0259	0.0247	0.0267	0.0237	0.0256
P15	0.0218	0.0219	0.0174	0.0204	0.0197	0.0214
P16	0.0248	0.0239	0.0247	0.0235	0.0217	0.0242
P17	0.0237	0.0222	0.0233	0.0220	0.0237	0.0230
P18	0.0237	0.0225	0.0233	0.0188	0.0257	0.0230
P19	0.0253	0.0251	0.0262	0.0251	0.0257	0.0253
P20	0.0239	0.0199	0.0218	0.0204	0.0217	0.0220
P21	0.0232	0.0228	0.0247	0.0235	0.0197	0.0230
P22	0.0244	0.0222	0.0218	0.0298	0.0237	0.0237
P23	0.0170	0.0168	0.0189	0.0157	0.0217	0.0172
P24	0.0228	0.0230	0.0247	0.0204	0.0257	0.0230
P25	0.0236	0.0197	0.0218	0.0235	0.0178	0.0218
P26	0.0203	0.0206	0.0218	0.0173	0.0296	0.0205
P27	0.0260	0.0265	0.0247	0.0283	0.0276	0.0263
P28	0.0228	0.0225	0.0233	0.0251	0.0217	0.0228
P29	0.0241	0.0251	0.0233	0.0220	0.0217	0.0241
P30	0.0250	0.0219	0.0189	0.0220	0.0237	0.0232
P31	0.0201	0.0205	0.0203	0.0157	0.0158	0.0197
P32	0.0251	0.0251	0.0262	0.0251	0.0178	0.0250
P33	0.0258	0.0262	0.0247	0.0267	0.0296	0.0261
P34	0.0223	0.0268	0.0233	0.0251	0.0237	0.0242
P35	0.0218	0.0233	0.0233	0.0251	0.0237	0.0228
P36	0.0228	0.0222	0.0262	0.0251	0.0237	0.0230
P37	0.0230	0.0222	0.0218	0.0267	0.0237	0.0229
P38	0.0221	0.0222	0.0247	0.0235	0.0217	0.0224
P39	0.0230	0.0233	0.0233	0.0251	0.0197	0.0231
P40	0.0228	0.0233	0.0247	0.0220	0.0197	0.0229
P41	0.0214	0.0202	0.0203	0.0220	0.0237	0.0210

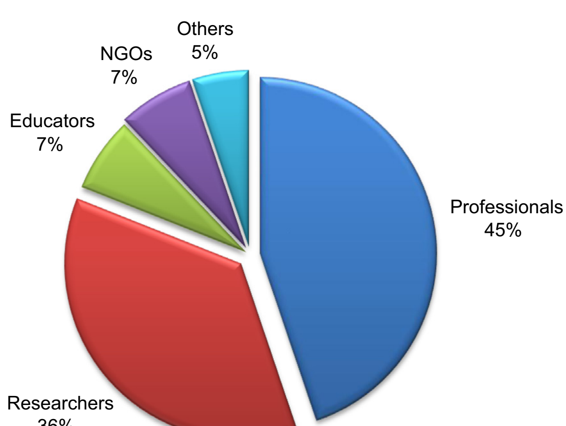

Fig. 1. Classification of Respondents.

(0.0247), *Losses in CSP* (0.0247) and *material used* (0.0247) have been given higher priorities by educators. *Type of CSP technologies* is again preferred by both NGOs and others with 0.0267 and 0.0296, followed by the second preference to *tracking* with 0.0267 and 0.0237 weightage respectively. *Module mounting structure* (0.0210) is given least preferred parameter by all.

In the end, responses of all the respondents are combined for individual parameter and the overall parametric assessment is obtained. It is observed that the *direct investment cost* (0.0268) got highest preference followed by *payback period* (0.0242) in economical parameters. Whereas *insurance cost* (0.0161) and *net salvage value* (0.0162) got least preference. From technical parameters side, *location of the site* (0.0268) is highly preferred followed by *CUF of the plant* (0.0256). In case of PV, highest priority is given to *type of cell used* (0.0263) followed by *performance ratio* (0.025). The *CPV* is least preferred (0.0197). In case of CSP, highest priority is given to *type of CSP technology used* (0.0261) followed by *thermal storage need* (0.0242). Least importance is given to *module mounting structure* (0.0210). The results for overall preference level are shown in Fig. 6. Final summary of the results obtained for professional, researcher and educators with overall consideration are shown in Table 5. Here the preferences by NGOs and others are not shown due to their small percentage in response.

From Table 5, it is inferred that the *direct investment cost* holds highest priority in overall scenario of economical parameters. This may be supported by the argument that the direct cost incorporates majority of investments and is crucial for the project development. The competitive nature of market and variation in the tariff rates for solar power electricity in different states of India

Table 4
Normalized parameters weightage for different groups.

Parameters	Professionals	Researchers	Educators	NGOs	Others	Overall
Economical Parameters (*A*)	0.0204	0.0206	0.0216	0.0205	0.0220	0.0207
Technical Parameters (*B*)	0.0233	0.0225	0.0227	0.0223	0.0234	0.0229
Parameters for PV (*C*)	0.0239	0.0236	0.0228	0.0230	0.0214	0.0235
Parameters for CSP (*D*)	0.0228	0.0233	0.0236	0.0246	0.0232	0.0232

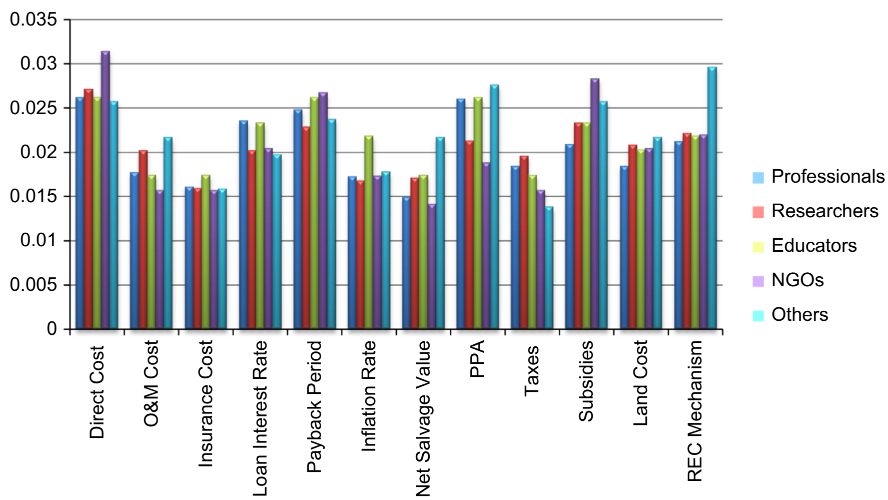

Fig. 2. Economical parameter preferences.

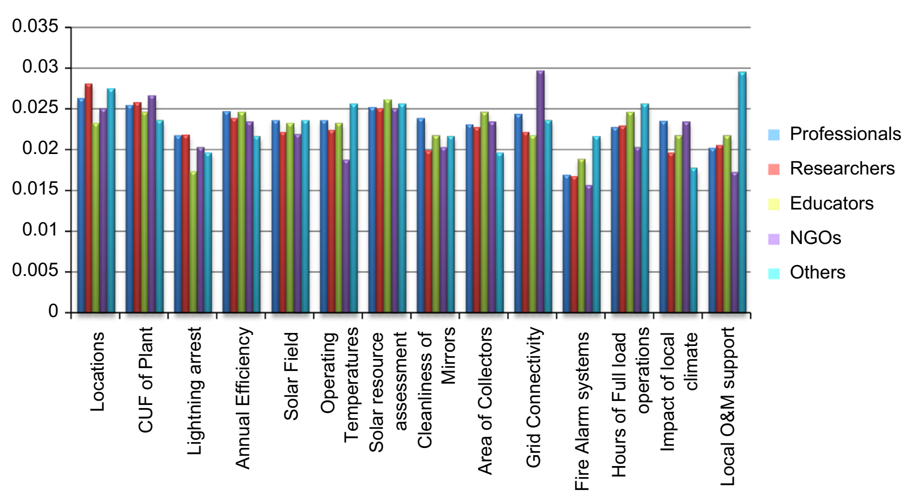

Fig. 3. Technical Parameters preferences.

might be the reason for resulting payback period as second priority. *Insurance cost* is given the least preference may be because of less chances of natural hazards in such systems.

In technical parameters, the *location of the plant* is most preferred. There may be several possible reasons, the major one being the land availability and consideration of solar insolation for the site. The land availability is the major issue in a populous country like India, which varies from state to state and it directly affects the direct cost and hence the project. That might be the reason of preferring it higher than the *CUF of the plant*, which is the second preference. CUF of plant measures how well a plant is utilized and it is of importance because a solar power plant is a costly asset with a limited life and the investor would like to extract as much value from the plant as possible. This might be the basis for its second priority. The need of *fire alarm system* is given the least preference because of the obvious reasons.

In case of PV technical parameters, the *type of cell used* is preferred unanimously by all respondents, may be because of the two reasons, first, efficiency and cost varies with the type of cell used and second, the type of cell determines the area for the solar panel per unit of power. The majority of respondents also felt the importance of *performance ratio*, which is worldwide accepted standard for measuring the performance of a PV plant and describes the relationship between the real and the theoretical possible energy output of a PV plant [43]. It is a very useful tool to compare PV plants across the world as it adjusts itself to the

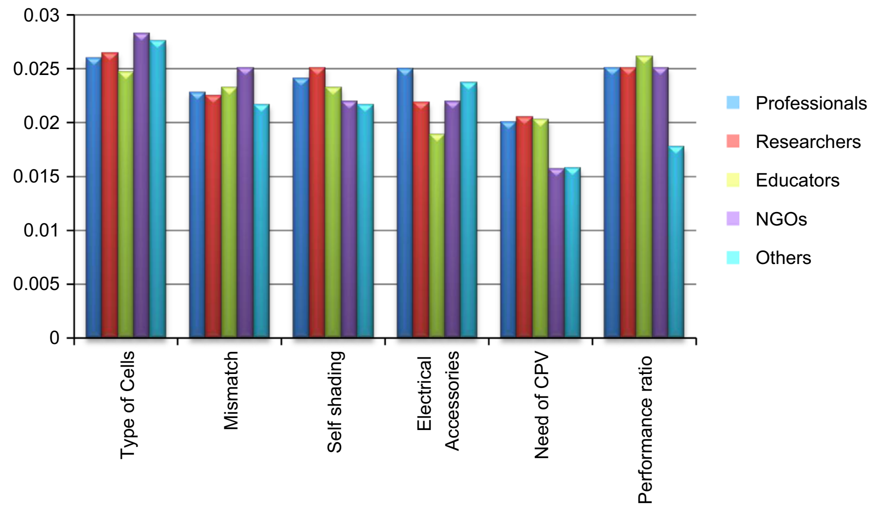

Fig. 4. PV Technical Parameters preferences.

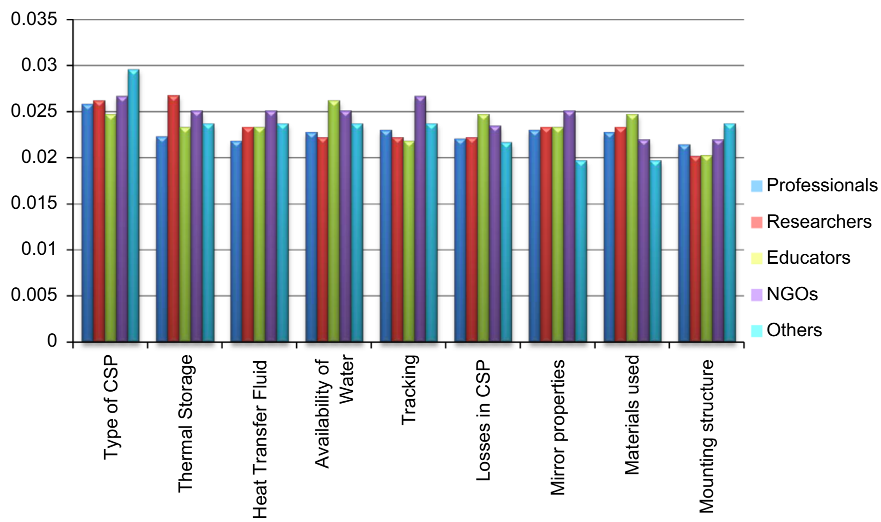

Fig. 5. CSP Technical Parameters preferences.

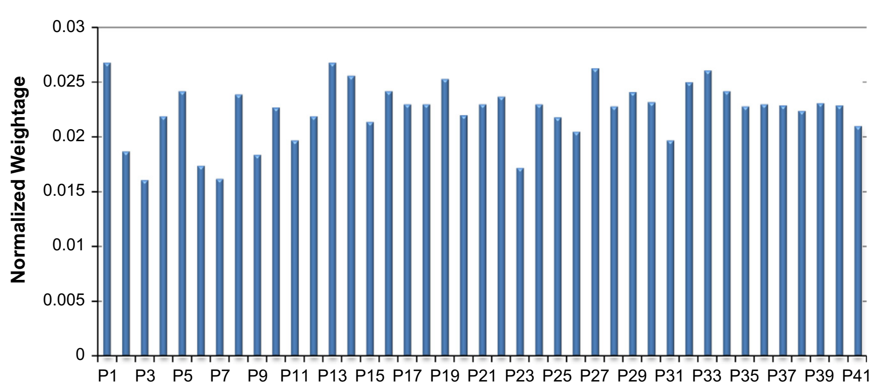

Fig. 6. Overall preference weightage.

location of plant and automatically discounts night times, when sun does not shine. On the other hand, CUF is useful in comparing different technologies and is particularly important to an investor who would like to know which technology offers maximum value [44]. In India, most of the project developers and investors use CUF as the standard of measuring the performance of a plant over the performance ratio. The lack of large capacity solar plants in India and choice of technology for investment might be the reason for this. The need of *CPV* is unanimously given least preference, shows that the perception of the respondents may be because PV, which is well established and commercially proven technology in the current market, while CPV is comparatively a new technology and

Table 5
Summary of preferences.

		Professionals	Researchers	Educators	Overall
Economical Parameters (*A*)	**1st Pref.**	Direct cost	Direct cost	Direct cost	Direct cost
	2nd Pref.	PPA	Government subsidies	Government subsidies	Payback periods
	Last Pref.	Net salvage value	Insurance cost	Insurance Cost	Insurance Cost
Technical Parameters (*B*)	**1st Pref.**	Location	Location	Solar resource assessment	Location
	2nd Pref.	CUF of plant	CUF of plant	Area of the collector	CUF of plant
	Last Pref.	Fire alarm system	Fire alarm system	Lightning arrest	Fire alarm system
PV Technical Parameters (*C*)	**1st Pref.**	Type of cell used	Type of cell used	Performance ratio	Type of cell used
	2nd Pref.	Performance Ratio	Performance Ratio	Type of cell used	Performance Ratio
	Last Pref.	Need of CPV	Need of CPV	Electrical accessories	Need of CPV
CSP Technical Parameters (*D*)	**1st Pref.**	Type of CSP used	Thermal storage	Easy availability of water	Type of CSP used
	2nd Pref.	Mirror properties	Type of CSP used	Type of CSP used	Thermal storage
	Last Pref.	Module mounting structure	Module mounting structure	Module mounting structure	Module mounting structure

the risk associated with CPV is not yet assessed in the Indian context, thus resulting in reluctance of market players to the implement/use this technology.

For CSP technical parameters, the *type of CSP* is given the top priority in overall case. The reason for this may be the required operating conditions of the plant. The temperature range varies from less than 100 °C to over 1000 °C thus giving the choice for type of CSP technology used. Also the CSP technologies are more effective with the use of thermal storages in order to get continuous power from the plant. This might be a possible explanation for the second preference of *thermal storages*. The *module mounting structure* is least preferred. One of the parameters, like the use of *tracking*, is given mixed preference by all the respondents. The reason for this might be though tracking increases the efficiency substantially there is also a substantial increase in the cost in PV, while in the case of CSP, tracking of the mirrors is a must.

The present work is unique and is of importance as it includes technical as well as economical parameters, which are not considered by other researchers like Bosetti et al. Their work was based on the expert elicitation survey from 16 experts only on PV cells and CSP as criteria for policy and decision making [32,33].

5. Conclusion

This paper discusses the results of survey conducted on the techno-economic parameters of solar technologies. The attributes taken for the survey are global and are from the literature review but, the data collection is only for Indian context. Any parameter which is not relevant to Indian scenario has been given as low preference by the respondents. For instance, as discussed above, CUF of the plant is preferred over performance ratio, though it is used globally for plants' performance. The results also shows the perception of Indian players towards the market growth with the commencement of JNNSM. It is the solar mission which targets for 20,000 MW installed capacity using solar by the year 2022. Of which, so far, around 2208.36 MW (as of January 2014) of solar power generation capacity has been achieved, majority of which is PV. It is expected to grow tremendously during Phase III (2017–2022). The installed capacity of CSP will also increase in the coming future as many large capacity plants are under construction in Rajasthan and Gujarat [19].

The present work can be a tool for the technical and economical assessment for the technology implementation in India. The results shows that, for both PV and CSP technologies, direct investment cost was highly preferred economical attribute, while the insurance cost is least preferred. Among technical parameters, location of the site is given top priority, while fire alarm system is given least favored. In PV, the type of solar cell used is preferred the most and the need of CPV the least, by all groups. In CSP, the type of CSP technology used is given top preference with slight variation in perception for other parameters. The module mounting structure is given last preference.

This study will help industrial players as well as government policy makers in decision making. As such type of study is unique of its kind in Indian context but can also be used as key step for the assessment of solar technologies in other developing nations. It would be interesting to see the comparison of such work for other countries which could be the future scope of this work.

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